# Comparison of The Mechanisms of Hydrogenation by RF Plasma And SiNx

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## ABSTRACT

In low temperature poly-silicon (LTPS) TFT's, the electrical characteristics are controlled by the inter- and intra-grain defects in the poly-silicon films. Hydrogen passivation is an effective way to reduce the density of these defects and can improve TFT's characteristics. In this study we investigated the characteristics of TFT's as a function of the hydrogenation time for two different hydrogenation techniques: $H_2$/Ar plasma and PECVD silicon nitride film deposition. It was found that the characteristics of TFTs could be greatly improved after a very short period of time by both hydrogenation processes. In the $H_2$/Ar RF plasma hydrogenation process, the characteristic parameters would be apparently improved within 30 min., and with only limited improvement after that. In the nitride hydrogenation process, the electrical characteristics of TFTs would be optimized within 5 min. of annealing, but started to degrade with longer annealing time. From these result, we concluded that the hydrogenation mechanism of these two techniques are very much different from each other.

**Keywords:** Low Temperature Poly-Si TFT, Hydrogenation, RF Plasma, Silicon Nitride.

## 1. INTRODUCTION

Low temperature poly-silicon (LTPS) TFTs fabricated by excimer laser crystallization on glass substrate have received increasing attentions recently for their applications in driver-integrated liquid crystal display.[1-3] The electrical characteristics of LTPS TFTs are dominated by the inter- and intra-grain defects in the poly-silicon films.[4-6] Hydrogen passivation is an effective way to reduce the density of these defects and improves TFT's characteristics. Hydrogen can be supplied by many methods, such as $H_2$ plasma,[1,2] PECVD silicon nitride deposition followed by high temperature annealing,[3,4] or hydrogen ion implantation.[7]

In this study we investigated the characteristics of TFTs as a function of the hydrogenation time for two different hydrogenation techniques: $H_2$/Ar plasma and PECVD silicon nitride deposition. And showed the difference of the mechanism of these two hydrogenation process.

## 2. EXPERIMENTS

The top-gate TFT's used in this hydrogenation experiment were fabricated on Corning 7059 glass. A 300 nm TEOS oxide was deposited by PECVD on the glass as the buffer layer to prevent contamination from surface of the glass. A 50 nm thick PECVD amorphous silicon (a-Si) film was then deposited at 450℃ and subsequently annealed at 400℃ for 2.5 hours under atmosphere to reduce the hydrogen content in the a-Si films. After the phosphorus dopping to define the n-type region by photo resist as mask, this a-Si film was crystallized by excimer laser at 400℃ and energy density 250 mJ/cm$^2$ which yielded a grain size of approximately 300 nm. The polycrystalline silicon island was defined by photolithography and dry etching process. A 100 nm TEOS oxide was deposited on the island as gate insulator and followed by gate metal deposition and patterning. Then 400 nm TEOS oxide was deposited as inter-layer, and the contact holes were patterned. Finally, a Cr/Al double-layer film was deposited and patterned as source/drain metal.

Figure 1 shows the cross-sectional structure of the top gate TFTs used in this study. The W/L is 50/20 μm. The devices were passivated by two hydrogenation techniques. The first one was based on directly immersing the whole devices in a $H_2$/Ar RF plasma. The second one used silicon nitride as a hydrogen source that was deposited on the devices by PECVD, and then the samples were baked at high temperature to out-diffuse the hydrogen.

## 3. RESULTS AND DISSCUSSION

Figure 2 shows the typical Id-Vg curves of the TFTs before and after hydrogenation with drain voltages at 10 V and 0.1 V. The electrical characteristics of the TFTs had an apparent improvement after hydrogenation.

The electrical parameters (mobility, sub-threshold swing, threshold voltage and minimum leakage current) were extracted and presented as a function of the hydrogenation time in Figure 3. It was found that the characteristics of TFTs would be apparently improved after a very short period of hydrogenation. In the H2/Ar RF plasma hydrogenation process, the characteristic parameters would be improved apparently in the first 30 min., and had further but limited improvement after that. And in the nitride hydrogenation process, the electrical characteristics of TFTs could be optimized in 5 min. of annealing, but the extended annealing time is detrimental to the TFTs.

In both techniques, hydrogen atoms have to diffuse through the interlayer oxide and gate oxide to reach the LTPS films. And these results indicate that the hydrogenation mechanism of RF plasma is different from that of PECVD silicon nitride. The density of monatomic hydrogen in the RF plasma remains at a constant level during the whole process, which makes a constant hydrogen concentration on the surface of the samples. The fast improvement of the characteristics of TFTs in the initial stage was due to the high hydrogen concentration gradient between RF plasma and the poly-silicon films. And as the hydrogen content in the devices increased with the hydrogenation time, the diffusion rate of hydrogen would gradually decrease by the Fick's law. This was reflected by the limited improvement of the electrical characteristics of TFTs after about 30 min. of hydrogenation. On the other hand, the monatomic hydrogen that PECVD silicon nitride can supply was limited by the hydrogen content of the nitride film. Although the electrical characteristics of TFTs could be optimized after 5 min. of annealing, it would degrade in the extended annealing process because of the hydrogen being trapped in the poly-silicon films would diffuse out, and with no further supplement of hydrogen atoms from the silicon nitride films. Therefore, the electrical characteristics of TFT's would gradually degrade.

## 4. CONCLUSION

In this work, we investigated the electrical characteristics of TFT's as a function of hydrogenation time by two different techniques: $H_2$/Ar plasma and PECVD silicon nitride film deposition. And it showed that the hydrogenation mechanism of these two techniques were very much different while both were very effective in improving the electrical characteristics of LTPS TFT's.

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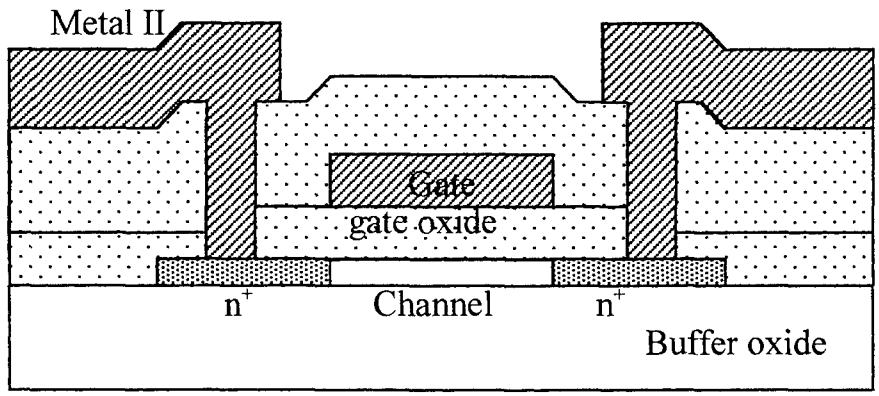


Figure 1. Cross-sectional structure of TFTs used for hydrogenation.

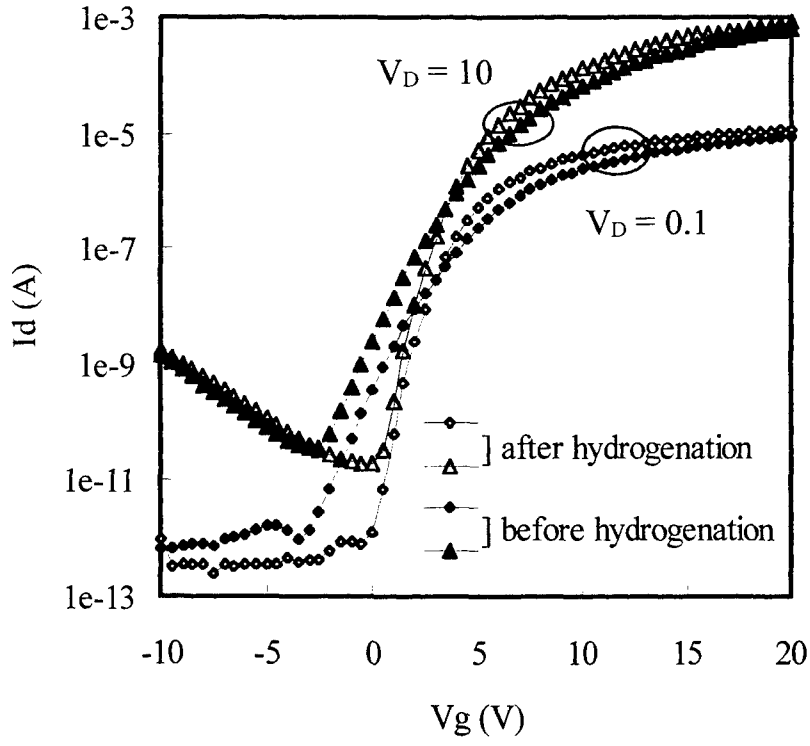


Figure 2. Typical $I_d$-$V_g$ curve before and after hydrogenation.

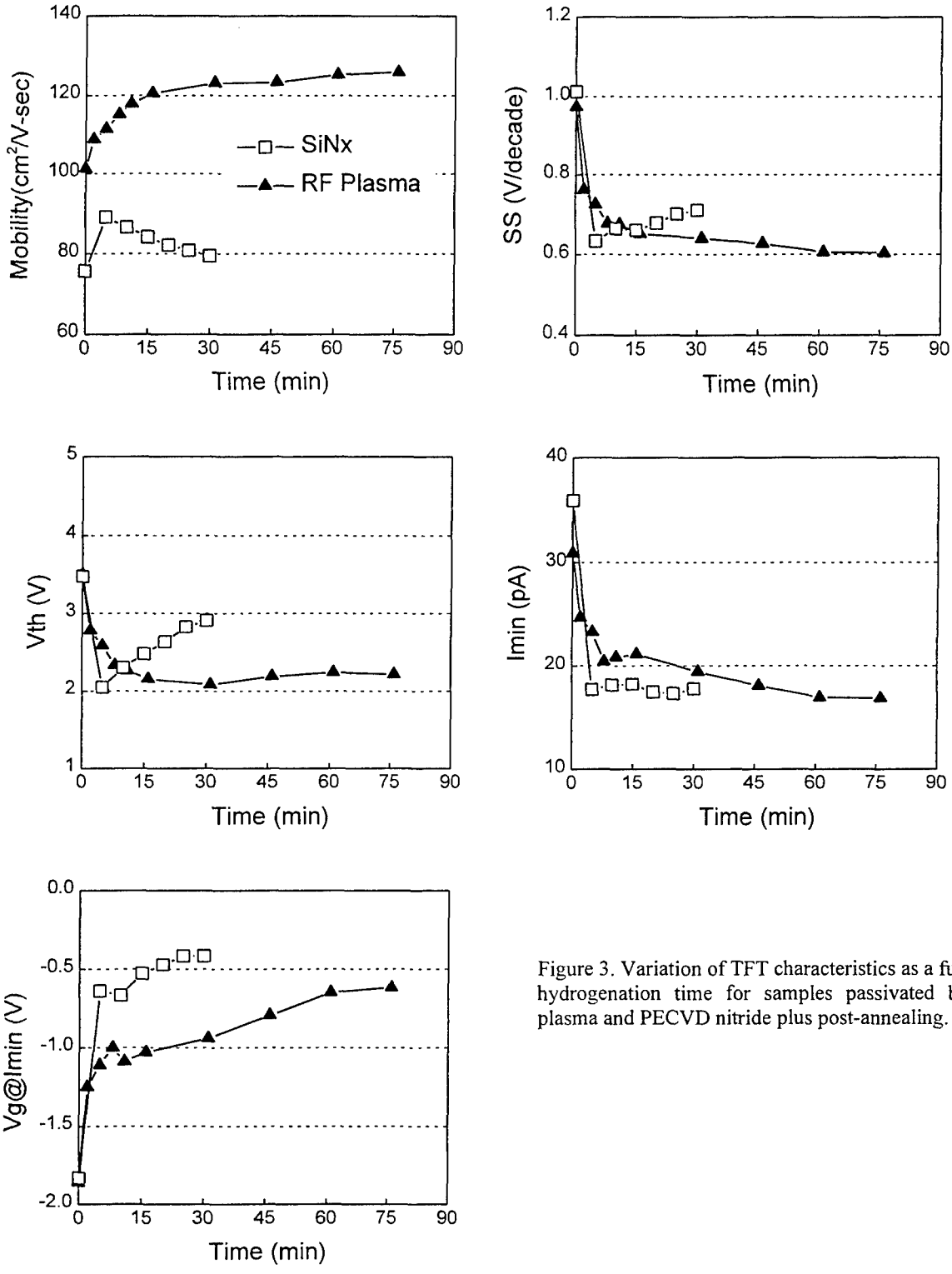


Figure 3. Variation of TFT characteristics as a function of hydrogenation time for samples passivated by $H_2$/Ar plasma and PECVD nitride plus post-annealing.